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TEXAS CLAYS AND THEIR ORIGIN.

BY W. KENNEDY, AUSTIN, TEXAS.

A SHORT time ago, while engaged in making a report on the clays of the State for the Geological Survey of Texas, I had occasion to study a large number of analyses made of clays belonging to the different Tertiary formations. During the course of the investigations it appeared to me that there was a peculiarity in the chemical composition of these clays not often seen among clays—that is, while in nearly every other clay to the analysis of which I had occasion to refer, and in which the alkalies, potash and soda were separated, the contained potash appears to exceed the percentage of soda, and in some instances this excess appears to be very great. In the Texas Tertiary clays, on the other hand, almost every one of the analyses made shows the soda to exceed the potash in ratios from 2 to 5 of soda to 1 of potash. As this excess varies in the different divisions, the difference generally increasing as we ascend in the beds, while at the same time the actual quantities of both decrease in the same ratio until the highest or coastal clays are reached, when the amounts of both are largely increased, I have been led to the opinion that this peculiarity might be due to the origin of the materials forming these deposits, or that some clue to their source might be obtained by a study of this phenomenon.

With this object in view, I have examined whatever analyses have been available of the deposits underlying or older than the Tertiary within the State, as well as the analyses belonging to the Tertiary and other beds found in the other States, so far as I have been able to obtain them, together with the analysis of the underlying deposits from which the clays may reasonably be expected to have been derived.

In the New Jersey clays, which, according to Cook, are of Cretaceous age and derived mostly from rocks lying to the southeast of the deposits, but which are now covered with water, or else completely destroyed, the percentages of potash and soda are 0.93 potash and 0.10 soda. In Ohio, according to Mr. Orton, the clays derived from the Carboniferous shales show averages of:

	Potash.	Soda.
5. Fire clays, - - - -	0.67	Traces
8. Potters' clays, - - - -	0.91	Traces
6. Pipe clays, - - - -	2.82	0.26
Or an average of - - - -	0.18	0.0137

In Kentucky, the next report examined, Dr. Peters shows the averages of the different formations to be:

	Potash.	Soda.
10. Tertiary fire clays, - - -	0.607	0.099
17. Coal-measure fire clays, - - -	0.537	0.407
5. Tertiary Potters' clays, - - -	0.814	0.208
3. Coal-measure Potters' clays, - - -	2.909	0.231
3. Black slate and Clinton clays, - - -	4.537	0.303
1. Middle Hudson clays, - - -	4.660	1.706

In Arkansas, according to Williams, the shales show the percentages of potash and soda to be:

	Potash.	Soda.
At Little Rock, - - - -	1.36	2.76
Round Mountain, - - - -	1.81	0.66
Fort Smith, - - - -	2.18	1.03

These shales belong to the Carboniferous, and it may be noted that the shales in the neighborhood of Little Rock are in close contiguity to the syenite area around Fourche Cove. Unfortunately no clay analyses showing the exact relations between the potash and soda in the Tertiary deposits are available from either Arkansas or Louisiana, into which many of the Texas Tertiary beds stretch with unbroken continuity.

Coming back to the fact that the Texas Tertiary clays are sodic clays, it is interesting to note that the immediately underlying deposits of Cretaceous age also carry an excess of potash over soda. The section of these beds appears to be roughly, in descending order, thus:

Greensand marls,
Marly flags,
Ponderosa (blue) marls,
Chalk marls,
Austin limestone.

The published analyses of these deposits show the percentages of potash and soda to decrease as we descend as follows:

	Potash.	Soda.
Greensand marls, - - - -	1.75	2.94
Ponderosa (blue) marls, - - - -	0.802	2.78
Chalk marl, - - - -	0.15	2.84
Austin limestone, - - - -	0.23	2.34
Average Cretaceous, - - - -	0.733	2.72

Going still further back in the deposits, the only analyses we have of the clays and shales of the Carboniferous show them to be also sodic and to carry a percentage of 3.09 soda and 1.53 potash, or closely approximating the ratio shown in the Tertiary basal clays and the lignitic beds.

The only analyses we have of the Texas kaolins show the west Texas materials to be practically free from alkalies and the Edwards County deposits to carry 0.02 of potash and 0.60 soda. An analysis of the basalt from Pilot Knob, near Austin, gave Professor Kemp 2.77 soda and 2.02 potash (*Amer. Geol.*, Nov., 1890). A kaolin from Pulaski County, Arkansas, shows 0.23 potash to 0.37 soda.

Clays naturally partake of the nature of the rocks from which they may have been derived, and the proportions of their constituents will in the same manner be in a ratio more or less in accordance with those of the parent rock, the variations being due to the solubility of the constituent and the number of changes to which it may have been subjected during the course of its transportation from the original locality to that in which we may find it. These changes are, however, sometimes extremely great, as, for instance, in the case of kaolin. Williams shows a kaolin in Arkansas, evidently derived from a syenite containing 5.48 potash and 5.96 soda, to have only 0.23 potash and 0.37 soda.

Since, then, the Texas Tertiary clays appear to be sodic,

where are we to look for their sources? Are they due to the destruction of the syenites of Arkansas or the basaltic outbreaks of which Pilot Knob is a representative, or must they be traced to a still more remote source among the eruptive and intrusive rocks of western or central Texas through the media of the Cretaceous, Carboniferous and other stages found in Texas?

Another question may be asked. The Tertiary deposits themselves give strong evidences of their being mostly of marine deposition, having throughout the greater portion of them a marine fauna. Had this condition of deposition anything to do with the quantities of soda found in the beds? Was it deposited from the waters of the sea and afterwards absorbed by the clays? Sodium chloride appears as an efflorescence in many portions of the area. Sodium occurs both as chloride and sulphate in nearly the whole of the mineral waters examined, and even the Greensand marls of the marine beds show, with but few exceptions, a large percentage of soda over the potash.

The few soils examined by the officers of the Geological Survey have also the same apparent constitution. Soda appears to exceed the potash.

It may also be of interest to find that, according to Dittmar, the relation of soda (Na_2O) to potash (K_2O) in ocean water is 100 to 3.23, and in kelp, according to Richardson, 100 to 5.26.

For geological purposes, the Texas Survey has divided the Tertiary deposits into five divisions, which may be briefly described, in ascending order, as follows:

First: The basal beds or Wills Point clays—This is a series of blue, bluish gray, yellow and brownish yellow clays, and gray, yellow and brown sands. These clays contain numerous small nodules of calcareous material, and crystals of selenite also occur in places. They also appear as fossiliferous in places. Boulders of fossiliferous limestones, with veins of calcite through them, occur scattered throughout the beds, although the heaviest proportion belong to the yellow-sand division—and occasional irregular deposits of heavy bedded white and grayish white highly fossiliferous limestones form a portion of these basal beds. These deposits lie immediately upon the marly deposits of the Upper Cretaceous, and may be said to have been deposited in small bay-like indentations along the Cretaceous shore line, or probably have suffered extensive erosion, as they now occur only as isolated patches in a few places along the Cretaceous border.

Second: The lignitic beds.—These deposits form the lowest portion of Dr. Penrose's Timber Belt beds and comprise a series of blue, brown, yellow, white and gray clays and sands, with extensive deposits of brown coal and lignite. The clays occur as thinly laminated, or stratified and massive, sometimes nearly free from sand; but the greater portion occurs as sandy or micaceous clays. Near the base these deposits consist of blue sands and clays, with occasional beds of gray and pinkish white or gray clays and thin deposits of brown sandstones. At the top they become a series of thinly-laminated and thinly-stratified red and white sands and clays, the laminae or strata usually not exceeding $\frac{1}{4}$ to $\frac{1}{2}$ inch in thickness, although the white-clay strata occasionally form beds from four to six feet in thickness. These, however, are very irregular, and when such a thickness of clay occurs it generally forms a pocket-like deposit extending over but a small area. The intermediate beds may be said to be blue and dark gray sands, clays and lignites—the lignites often attaining a thickness of from six to sixteen, and even more, feet. These lignite beds are probably the most extensively developed Tertiary deposits within that portion of the coastal plain in the State. Nor are they confined to Texas alone, but occur farther east in both

Arkansas and Louisiana. In the northeastern portion of the State they have a known thickness of 1,000 feet, wells bored in that region from 800 to 1,000 feet having failed to pierce them; and at Mineola, in Wood County, the base of these beds was not reached in a well 1,200 feet in depth. These beds contain vast deposits of clays of all sorts, including plastic potters' clay and refractory clays showing an analysis equal to the best Stourbridge, as well as clays suitable for the manufacture of the finest grades of porcelain.

Third: The Marine beds.—Succeeding the lignitic beds and overlying them in direct continuity comes a series of sands, clays and iron ores, the greater portion of which is highly fossiliferous, containing in many places an abundant marine fauna. These beds have an aggregate thickness of over 600 feet. Abundant deposits of limonite and greensand marls occur throughout them, but the clays are generally poor and very irregularly deposited.

Fourth: The Yegua beds.—The fourth great division has been called the "Yegua clays" from their development on the river of that name. These clays form the base of Dr. Penrose's Fayette Beds, and the division comprises a series of dark blue and gray clays and brown and gray sands and sandy clays, with great quantities of selenite in crystals from nearly six inches in length down to sizes almost microscopic. The water found in these beds is strongly saline, and in many portions of the area underlain by them, especially where the dark blue clays approach the surface, the gray overlying sands show patches of saline efflorescence. Many of the gray clays belonging to this series contain leaves and stems of plants, and heavy deposits of lignites also occur at many places within the same area.

Fifth: The Fayette Sands.—This division has been called the Fayette Sands chiefly on account of its being made up largely of gray sands and sandstones, although, however, it contains many deposits of very fine white and gray clays, many of which when washed showing decided kaolinitic conditions. These deposits are also more or less fossiliferous, showing at places a scanty marine fauna of the Eocene series, and closely connecting them with the yellow and brown sands of the marine beds already referred to. In the sands belonging to this division great quantities of beautifully opalized wood occur. Beds of a very fine white silicious earth or sinter occur at several places within this area, and the enormous quantities of gray sandstone used at Galveston and Sabine Pass for jetty purposes are obtained from these beds. Many of the clays and coarse sandstones belonging to the upper portion of the Fayette beds are highly calcareous, and in places show small quantities of well-worn Cretaceous shells.

Overlying the Fayette sands there appears a series of heavy-bedded, blue, red, green and yellow and sometimes white clays, with brown and grayish white sands containing small patches of pink clay. These are pretty generally ascribed to the Tertiary age, but their exact position is as yet a matter of doubt. The blue clays contain an abundance of calcareous nodules scattered throughout them, although these nodules appear to be wanting in the immediately underlying red clays, and are not very plentiful in the overlying yellow and green deposits. These deposits have not yet received a specific name. They have been described in the Third Annual Report of the Survey under the title of the Fleming beds. Since then, however, more extended research has been made in these beds in southwestern Texas, and Mr. Dumble proposes to assign to the whole division the name of "Frio Clays."

The last division of our clay deposits is known as the Coastal Clays. These occupy an area of from 75 to 100

miles in width along the coast, and comprise a series of blue, brown, yellow and variously colored clays, many of which are highly calcareous.

With probably the exception of the basal beds, which, as has already been stated, appear to be somewhat irregularly distributed along the contact between the Tertiary and the underlying Cretaceous, the whole of these deposits may be considered as lying in a series of irregular belts roughly parallel to the present coastal line, while a section drawn across them almost anywhere would show each to have an abrupt exposure towards the northwest. In other words, while the dip is approximately southeast, the northwestern edge appears usually as an escarpment showing the broken ends of the beds, and in places these escarpments have deflected the courses of several of the rivers crossing the Tertiary area. These rivers also appear to be working southward, showing high steep bluffs along their southern sides, while broad flat bottom lands appear along their northern banks. Such also appears to be the course of operations with all the larger streams running in an easterly or westerly direction.

A peculiarity noticeable among the lower divisions of these deposits is a flexing or bending of the beds, beginning in the lignitic, and, so far as at present known, reaching the culminating point towards the top of the marine beds. This flexing has resulted in making many of the higher hills of erosion and the tops portions of the synclines.

From this brief outline it will be seen that the greater portion of the Tertiary areas is made up of extensive beds of clays and sands.

The analyses of these clays made by the different chemists of the Geological Survey show them to have the peculiarity of having the proportions of the alkalis potash and soda reversed. In the greater number of clay analyses which I have had occasion to refer to, the proportion or percentage of potash exceeds that of the soda. In the Tertiary clays of Texas the proportions of soda exceed the potash as 3.19 of soda to 1.18 of potash. These proportions vary in the different stages, as will be seen in the following:

	Potash.	Soda.
1. Basal beds, - - - -	1.53	3.64
2. Lignitic beds, - - - -	1.35	3.42
3. Marine beds, - - - -	0.91	2.32
4. Yegua beds, - - - -	1.07	2.33
5. Fayette beds, - - - -	0.67	1.93
6. Fleming (Freo) beds, no analyses made.		
7. Coastal clays, - - - -	1.56	5.52

From this it will be seen that there is a gradual decline of the two alkalis as we ascend until the coastal clays are reached, when the soda shows a sudden increase over the basal beds almost equal to the sum of the losses it sustains in the other members of the series, while its actual increase over the Fayette beds amounts to 3.55. The potash also shows an increase in these beds over the basal clays of only 0.03, and over the Fayette beds of 0.88, or about equal to the sum of the losses sustained in its course through the deposits from the lignitic to the Fayette.

The question of the origin of these clays involves the existence of an extensive land area of deposits in which the alkalis were strongly represented, and, assuming the solubility of the two to be approximately similar (as a matter of fact the potash is slightly more soluble), one in which the soda was considerably more abundant than the potash. Again, throughout the deposits and interbedded with the clays we have heavy beds of sand, many of them almost pure quartz, and the greater portion of the clays themselves are highly silicious. In addition, the immense deposits of limonite found interstratified with and cover-

ing the marine stage of these deposits will require to be accounted for.

It appears to me that the most probable immediate sources of the materials entering into the composition of these Tertiary deposits are the underlying cretaceous beds for the lowermost or basal Tertiary, and a partial reworking of the older Tertiary with the cretaceous materials for the upper or newer deposits. These cretaceous marls and marly clays correspond very closely to the Tertiary deposits, as will be seen from the following analyses:

	I. Av. of 59 Tertiary Analyses.	II. Av. of 8 Cretaceous Analyses.	III.
Silica, - - -	65.63	31.67	59.34
Alumina, - - -	14.84	9.92	18.59
Iron, - - -	4.83	3.36	6.30
Lime, - - -	3.19	26.68	3.19
Magnesia, - - -	0.30	Trace	Trace
Potash, - - -	1.03	0.73	1.37
Soda, - - -	2.65	2.72	5.01
Carbonic acid, - - -	-	20.95	-
Sulphuric acid, - - -	0.57	1.04	5.67
Water and loss, - - -	7.11	2.97	.57
	100.15	100.04	100.04

The third column shows the average of the Cretaceous analyses re-calculated without the carbonate of lime and carbonic acid and omitting a portion of the sulphuric acid, which would undoubtedly be lost during the course of erosion and deposition, and which we might expect to find farther to the south among the more recent of the Tertiary deposits as well as in the coastal clays. The percentages of lime and sulphuric acid shown in this analysis are the averages shown in the Tertiary deposits. The course of the lime through the different sets of beds appears to be thus:

Basal beds, - - -	2.05
Lignitic beds, - - -	0.77
Marine beds, - - -	1.97
Yegua beds, - - -	0.43
Fayette beds, - - -	10.75

Many of these Fayette clays contain as high as 24.42 per cent of lime and 18.91 per cent of carbonic acid. Among the sandstones belonging to the upper division there are many beds which might be classified as calcareous sandstones, some of them containing enough lime to have made it profitable at one time to use them as a source of lime for building purposes. Their derivation from Cretaceous deposits is also indicated by the existence of numerous water-worn Cretaceous shells.

The coastal clays contain immense quantities of lime at different points, and nothing short of an immense number of analyses could give us anything like a fair average. They have not been included in any of the above analyses.

The basal beds of the Tertiary so strongly resemble the upper and contiguous beds of the Cretaceous in lithological as well as chemical structure that it is very difficult to tell them apart, and in many portions nothing but a study of the fauna will enable anyone to differentiate the two, and in many places the Tertiary beds contain boulders and fragments of Cretaceous limestones containing Cretaceous fossils.

It would thus appear that the structural conditions of the Basal beds and the Fayette deposits, apart from any chemical evidence whatever, bears out the assumption of these two divisions being derived from the Cretaceous. If we accept Dr. Penrose's theory that the iron ores and glauconite of the marine beds are largely due to the destruction of the upper glauconitic division or the greensand of the Cretaceous, and in this theory, from a long period of work among these beds, I am inclined to believe for several reasons—one of which being the close affinity chemically and otherwise of these beds. Then that will in

a great measure dispose of the origin of the middle great division.

Now whether the great series of deposits immediately overlying the marine beds—the Yegua clays—have been altogether derived from the erosion and consequent destruction of the marine beds is not very clear. That a portion of the materials composing these clays was so derived there can be no doubt. The line of contact between the two is very irregular in more than one place, showing long troughs or valleys of erosion in the older beds, and now filled up by the clays and sands of the newer. At other places this outline shows the existence of comparatively bold head-lands, from which no doubt the waters of Yegua time abstracted a considerable quantity of material. The presence of extensive deposits of lignites in these beds would appear to indicate another source of material having a swamp or lagoon origin, and some of it may have been obtained from the rivers traversing the region. Some of the materials employed in the formation of these beds may also have been derived from the sea water occupying the area during the period of deposition.

The last division, or more properly speaking, the second division—the lignitic beds—presents somewhat different features from any of the others. So far as it contains immense deposits of lignite and small beds of sand carrying crystals of selenite, it resembles the Yegua clays, but with that its resemblance ceases. The beds belonging to this division overlie the basal deposits, which in many places they overlap so completely as to obscure them altogether, and in others lie in direct contact with the Cretaceous deposits. Throughout the whole of the immense thickness and extent of these beds, with the exception of a few fragmentary plant remains, some of them belonging to the *sabal* family, not a single fossil is known from this division. Evidently the conditions were not favorable to animal life.

These beds apparently represent a period when the whole coast was made up of swamps, lagoons and bayous, very similar to some portions of the gulf coast of the present day, or what may be seen in the broad stretches of overflow or "bottom" land found along almost every one of our rivers. A rank vegetation grew on the marshy portions, and the rivers of the time having no fixed channels, distributed their waters throughout the lagoons and bayous and into them, and over the low islands carried their burdens of debris during periods of flood. With this debris came soft clay, sand, branches, limbs and trunks of large trees, all of which went to swell the accumulations already gathering and aid in the formation of the lignites and their associated beds of clay and sand. In the meantime the coast was slowly sinking and the encroaching water eating away the basal clays and the Cretaceous deposits within reach.

The lithological structure of these deposits accord with these conditions. Everywhere the deposits are irregular in deposition, variable in texture, changing from fine-grained, dense, muddy, to coarse-grained, sandy material within short distances. Many of the beds contain great quantities of iron pyrites, a common characteristic of the Cretaceous greensand marls. In composition these lignitic beds closely resemble these marls.

	IV. Av. of 38 analyses of lignitic clays.	V. Cretaceous greensand marls.
Silica,	69.83	60.82
Alumina,	16.93	16.05
Iron,	3.66	5.25
Lime,	0.77	3.66
Magnesia,	0.35	
Potash,	1.35	1.75
Soda,	3.42	2.94

Sulphuric acid,	0.22	1.06
Carbonic acid,		2.85
Water and loss,	4.26	5.53
	100.79	99.91

From this, then, it would appear that while the greater portions of these clays and sands are derived from Cretaceous materials, these have been mixed with a small quantity of ingredients belonging to some of the older formations through which the larger rivers ran; but the proportions of these older materials were so small as not to visibly affect the deposits as a whole.

Mention has been made of the syenitic rocks of Arkansas and the basaltic outbreaks extending through the Texas Cretaceous area as forming the source of some of the materials found in the clays. These I do not think can have contributed any of the materials required. No very decided evidence of the age of these rocks has been given, but the general opinion as stated by Branner and Williams appears to be that the age of the Arkansas rocks is either late Cretaceous or early Tertiary, and certainly not newer than this time. According to Hill, Pilot Knob belongs to the upper Cretaceous and the latter half of Austin Chalk sub-epoch. If these ages are accepted, then certainly the rocks in question had nothing to do with the formation of the Texas Tertiary clays.

KARYOKINESIS IN EMBRYOS OF THE DOMESTIC CAT.—PRELIMINARY NOTICE.

BY FRANK S. ABY, HISTOLOGICAL LABORATORY, STATE UNIVERSITY OF IOWA.

IN all sections of various embryo kittens that have been examined by the writer, up to those of embryos seventeen millimetres in length, karyokinetic figures are by no means an occasional or a rare occurrence, but are to be found in many situations.

In the preparation of these sections, no special cytological methods were employed, as the subject of investigation was the development of the central nervous system of the cat. The embryos were hardened in increasing strengths of alcohol, with no precautions whatever with regard to fixation. After remaining in 95 per cent alcohol for a number of months the embryos were imbedded in celloidin and sectioned. The sections were then stained in Grenacher's haematoxylin and mounted in Canada balsam.

The resting nuclei are spheroidal occasionally, but the more usual form is that of an elongated oval. Occasionally very peculiar, irregular nuclei are found, and one was seen whose length was three times its width, without the aggregation of chromatin to be described later, but with a clearly marked reticulum and nuclear membrane. Usually the nuclear membrane is not shrivelled or wrinkled in hardening, but is plump and distinct, clear cut on its outer line, and in almost all cases has taken a deep stain.

The chromatin in these resting nuclei is disposed in a reticulum that strongly reminds one of the bridges seen in plant cells. This reticulum is clearly continuous with the nuclear membrane, as may be seen in very numerous instances, the point of union of a strand and the nuclear membrane presenting a well-defined enlargement of the strand. In some nuclei which happen to lie in the proper position several of these points of union in a single nucleus appear in the same plane, giving the nuclear membrane the appearance of being toothed.